

WHAT IS CLAIMED IS:

1 1. A method of scheduling a media object for transmission between a
2 server and a client, the method comprising:
3 partitioning the media object into segments of blocks, wherein each block is a
4 unit of media for which the client will wait to receive an entire block before playing out the
5 block, and wherein each segment includes an integer number of blocks;
6 determining one or more channels on which to serve each segment, the
7 channels capable of carrying data between the server and the client;
8 determining a rate at which to serve each segment; and
9 determining a schedule pair for each channel, the schedule pair including a
10 time at which the client may start receiving on the channel and a time at which the client may
11 stop receiving on the channel.

1 2. The method of claim 1 wherein if the client minimally fulfills the
2 schedule pair for each channel, the client will be able to play out the media object
3 uninterrupted after a startup latency.

1 3. The method of claim 1 wherein the partitioning step includes first
2 partitioning the media object into segments, then partitioning each segment into an integer
3 number of blocks.

1 4. The method of claim 1 wherein the partitioning step includes first
2 partitioning the media object into blocks, then grouping the blocks into segments.

1 5. The method of claim 1 wherein a maximum download rate at the client
2 is less than an aggregate server transmission rate.

1 6. The method of claim 1 wherein a maximum download rate at the client
2 is unconstrained.

1 7. The method of claim 1 wherein a maximum download rate at the client
2 is only slightly greater than a media object play out rate.

1 8. The method of claim 1 wherein a maximum download rate at the client
2 is less than a media object play out rate.

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- 1 9. The method of claim 1 wherein at least one segment includes more
2 than one block.
 - 1 10. The method of claim 1 wherein each segment includes exactly one
2 block.
 - 1 11. The method of claim 1 wherein a plurality of blocks in a segment are a
2 same size.
 - 1 12. The method of claim 1 wherein a plurality of blocks in a plurality of
2 segments are a same size.
 - 1 13. The method of claim 1 wherein at least two of the channels are served
2 at different rates.
 - 1 14. The method of claim 1 wherein at least two segments have different
2 sizes.
 - 1 15. The method of claim 1 wherein each block in each segment is served at
2 a same rate.
 - 1 16. The method of claim 1 wherein at least one block in at least one
2 segment is served at a rate different than other blocks in the segment.
 - 1 17. The method of claim 1 wherein the segments are served at a rate less
2 than a play out rate.
 - 1 18. The method of claim 1 wherein at least one segment is served on at
2 least two channels, and wherein each of the at least two channels is served at a rate.
 - 1 19. The method of claim 18 wherein the each of the at least two channels
2 are served at a same rate.
 - 1 20. The method of claim 18 wherein at least two of the each of the at least
2 two channels are served at different rates.
 - 1 21. The method of claim 1 wherein the number of channels is less than or
2 equal to a maximum number of concurrent channels at the client.

1 22. The method of claim 2 wherein the client can minimally fulfill the
2 schedule pair for each channel by downloading from a maximum number of concurrent
3 channels.

1 23. The method of claim 1 wherein the number of channels is less than or
2 equal to a maximum number of concurrent channels served by the server.

1 24. The method of claim 1 wherein the partitioning, determining one or
2 more channels, determining a rate, and determining a schedule pair steps are performed so as
3 to optimize a server bandwidth required to serve the media object.

1 25. The method of claim 1 wherein the partitioning, determining one or
2 more channels, determining a rate, and determining a schedule pair steps are performed so
3 that the media object is served to the client at a rate less than or equal to a maximum client
4 download rate.

1 26. The method of claim 1 further comprising, for each of the plurality of
2 segments, determining a size of the segment so that the segment is completely downloaded
3 by the client prior to when the segment is due to be played out.

1 27. The method of claim 26 wherein, for each of the plurality of segments,
2 the rate at which to serve the segment is an integer multiple of a base rate.

1 28. The method of claim 26 wherein all of the segments are served at a
2 same rate.

1 29. The method of claim 1 further comprising, for each of a plurality of
2 segments:

3 if the segment may be scheduled to be served to the client without exceeding a
4 maximum client download rate, scheduling the segment to be served to the client; and

5 if the segment may not be scheduled to be served to the client without
6 exceeding the maximum client download rate, waiting to schedule the segment to be served
7 until one or more other segments are scheduled to end being downloaded at the client.

1 30. The method of claim 1 wherein the partitioning, determining one or
2 more channels, determining a rate, and determining a schedule pair steps are performed so as
3 to optimize a number of concurrent channels at the server required to serve the media object.

1 31. The method of claim 1 wherein sizes of a plurality of blocks are each
2 less than or equal to a maximum block size.

1 32. The method of claim 1 wherein sizes of a plurality of segments are
2 each less than or equal to a maximum segment size.

1 33. The method of claim 32 wherein the maximum segment size is based
2 on a maximum available storage at the client.

1 34. The method of claim 1 wherein sizes of a plurality of blocks are each
2 greater than or equal to a minimum block size.

1 35. The method of claim 34 wherein the minimum block size is
2 determined by an encoding scheme.

1 36. The method of claim 34 wherein the minimum block size is
2 determined by a media object player data format.

1 37. The method of claim 1 wherein the partitioning step includes, for each
2 of a plurality of segments, determining a start point of the segment and an end point of the
3 segment based upon requirements of a media object player data format.

1 38. The method of claim 1 wherein the partitioning step includes, for each
2 of a plurality of blocks, determining a start point of the block and an end point of the block
3 based upon requirements of a media object player data format.

1 39. The method of claim 1 wherein the rate and the schedule pair are based
2 on a maximum available storage at the client.

1 40. The method of claim 1 wherein the rate varies over time.

1 41. The method of claim 1 wherein at least one segment is served on at
2 least two channels, and wherein a rate at which the segment is served on one of the at least
3 two channels varies over time.

1 42. The method of claim 1 wherein a set of channels serving at least one
2 segment varies over time.

1 43. A system for scheduling a media object for transmission between a
2 server and a client, comprising:

3 a module for partitioning the media object into segments of blocks, wherein
4 each block is a unit of media for which the client will wait to receive an entire block before
5 playing out the block, and wherein each segment includes an integer number of blocks;

6 a module for determining one or more channels on which to serve each
7 segment, the channels capable of carrying data between the server and the client;

8 a module for determining a rate at which to serve each segment; and

9 a module for determining a schedule pair for each channel, the schedule pair
10 including a time at which the client may start receiving on the channel and a time at which
11 the client may stop receiving on the channel.

1 44. A method of serving a media object, the method comprising:

2 receiving segments of a media object, wherein each segment includes an
3 integer number of blocks, wherein each block is a unit of media for which a client will wait to
4 receive an entire block before playing out the block, and wherein each block includes one or
5 more input symbols;

6 for each segment, receiving an indication of one or more channels on which to
7 serve the segment;

8 for each segment, receiving a rate at which to serve the segment;

9 determining an order in which to encode blocks;

10 generating output symbols for each block in the order; and

11 transmitting the output symbols on the corresponding one or more channels,

12 wherein each segment is served at the corresponding rate.

1 45. The method of claim 44 further comprising providing one or more
2 storage devices on which to store the media object.

1 46. The method of claim 44 wherein the receiving a rate step includes
2 receiving an aggregate rate at which to serve the segment on the one or more channels.

1 47. The method of claim 44 wherein the receiving a rate step includes, for
2 each of the one or more channels on which to serve the segment, receiving a rate at which to
3 serve the segment on the each of the one or more channels.

1 48. The method of claim 44 wherein a server serves at least two media
2 objects concurrently.

1 49. The method of claim 44 wherein a media object is concurrently served
2 on at least two servers.

1 50. The method of claim 49 wherein at least one segment is concurrently
2 served on at least two servers.

1 51. The method of claim 49 wherein at least one segment is served on only
2 one server.

1 52. The method of claim 44 wherein the media object is served on unicast
2 channels.

1 53. The method of claim 44 wherein the media object is served on
2 multicast channels.

1 54. The method of claim 44 wherein the media object is served on
2 broadcast channels.

1 55. The method of claim 44 wherein generating output symbols includes
2 using a chain reaction code to generate output symbols.

1 56. The method of claim 44 wherein generating output symbols includes
2 using a FEC code to generate output symbols.

1 57. The method of claim 56 wherein all of the output symbols in a block
2 are generated before transmitting any of the output symbols in the block.

1 58. The method of claim 56 wherein for some or all of the plurality of
2 output symbols, each of the some or all of the output symbols is generated upon a first
3 transmission of the output symbol on the channel.

1 59. The method of claim 56, further including determining an order in
2 which to transmit output symbols corresponding to a block, and wherein transmitting output
3 symbols includes transmitting output symbols corresponding to a block in the order.

1 60. The method of claim 59 wherein the order is determined according to a
2 random or pseudo-random sequence.

1 61. The method of claim 44, further including determining an order in
2 which to transmit output symbols for each block in a segment, and wherein transmitting
3 output symbols includes, for each segment, transmitting output symbols corresponding to
4 each block in the order.

1 62. The method of claim 61 wherein the order is determined according to a
2 random or pseudo-random sequence.

1 63. The method of claim 44 wherein input symbols are used as output
2 symbols.

1 64. The method of claim 44 wherein a server transitions between serving a
2 first media object and a second media object by successively stopping the serving of
3 segments for the first media object and successively starting the serving of segments for the
4 second media object.

1 65. The method of claim 44 wherein the rate at least one segment is served
2 on a channel varies over time.

1 66. The method of claim 44 wherein at least one segment is served on at
2 least two channels.

1 67. The method of claim 44 wherein, for at least one segment, the one or
2 more channels on which the segment is served varies over time.

1 68. An apparatus for serving a media object, comprising:
2 a block encoder coupled to receive segments of a media object, wherein each
3 segment includes an integer number of blocks, wherein each block is a unit of media for
4 which a client will wait to receive an entire block before playing out the block, wherein each
5 block includes one or more input symbols; the block encoder including an input to receive an

6 order in which to encode the blocks; and wherein the block encoder is configured to generate,
7 in the order, output symbols for each block; and

8 a transmitter coupled to receive the output symbols from the block encoder,
9 and coupled to receive, for each segment, an indication of one or more channels on which to
10 serve the segment and a rate at which to serve the segment;

11 said transmitter configured to serve the output symbols on the corresponding
12 one or more channels at the corresponding rate.

1 69. A method of receiving a media object that includes segments of blocks,
2 wherein each segment includes an integer number of blocks, and wherein each block is a unit
3 of media for which a client will wait to receive an entire block before playing out the block,
4 the method comprising:

5 receiving a media object description of the media object;
6 joining and leaving each of a plurality of channels according to the media
7 object description to download the segments;
8 reassembling the blocks in each segment; and
9 playing the blocks out in an order after a startup latency.

1 70. The method of claim 69 wherein a client joins channels according to an
2 order in the media object description.

1 71. The method of claim 69 wherein, reassembling the blocks of a first
2 segment and playing out the blocks of a second segment occur concurrently.

1 72. The method of claim 69 wherein segments are downloaded on unicast
2 channels.

1 73. The method of claim 69 wherein segments are downloaded on
2 multicast channels.

1 74. The method of claim 69 wherein segments are downloaded on
2 broadcast channels.

1 75. The method of claim 69 wherein a plurality of segments are
2 downloaded concurrently at an aggregate rate, and wherein the aggregate rate is less than a
3 maximum download rate.

1 76. The method of claim 69 wherein the media object is downloaded by a
2 client at a rate less than an aggregate server transmission rate.

1 77. The method of claim 69 wherein the media object is downloaded by a
2 client at an unconstrained rate.

1 78. The method of claim 69 wherein the media object is downloaded by a
2 client at a rate only slightly greater than a media object play out rate.

1 79. The method of claim 69 wherein the media object is downloaded by a
2 client at a rate less than a media object play out rate.

1 80. The method of claim 69 wherein joining and leaving a plurality of
2 channels includes downloading at least a first segment upon the ending of the downloading of
3 a second segment.

1 81. The method of claim 69 wherein a rate at which the media object is
2 downloaded may be adjusted by joining and leaving channels.

1 82. The method of claim 81 wherein a client increases its reception rate by
2 adding channels according to an order and decreases its reception rate by dropping channels
3 either in a reverse of the order, or when a segment completes downloading on that channel.

1 83. The method of claim 81 wherein a client increases its reception rate
2 when it experiences no congestion and decreases its reception rate when it experiences
3 congestion.

1 84. The method of claim 69 wherein the blocks include original data, and
2 wherein reassembling the blocks in each segment includes reordering the original data
3 according to its temporal position in each block.

1 85. The method of claim 69 wherein reassembling the blocks in each
2 segment includes decoding with a FEC decoder.

1 86. The method of claim 69 wherein reassembling the blocks in each
2 segment includes decoding with a chain reaction decoder..

1 87. The method of claim 69 wherein a single media object is downloaded
2 from at least two servers.

1 88. The method of claim 87 wherein at least one segment is downloaded
2 from at least two servers.

1 89. The method of claim 87 wherein at least one segment is downloaded
2 from only one server.

1 90. The method of claim 69 wherein a same segment in the media object is
2 downloaded from at least two servers.

1 91. The method of claim 69 further comprising playing out a pre-
2 downloaded segment during the startup latency.

1 92. The method of claim 69 wherein the media object is downloaded by a
2 client from a maximum number of channels concurrently.

1 93. The method of claim 69 wherein a set of channels on which at least
2 one segment is downloaded varies over time.

1 94. A system for receiving a media object that includes segments of
2 blocks, wherein each segment includes an integer number of blocks, and wherein each block
3 is a unit of media for which a client will wait to receive an entire block before playing out the
4 block, comprising:

5 a module for handling input of a media object description of the media object;
6 a module for handling channel joins and channel leaves for each of a plurality
7 of channels according to the media object description, wherein the channels are capable of
8 use for downloading the segments to the client;

9 a module for reassembling the blocks in each segment; and
10 a module for playing the blocks out in an order after a startup latency.